INTELLIGENT MODELS AND ALGORITHMS FOR DEREGULATED ELECTRICITY MARKET

A

SYNOPSIS

SUBMITTED TO THE

MANAV RACHNA UNIVERSITY, FARIDABAD

FOR THE DEGREE

OF

DOCTOR OF PHILOSOPHY

IN

(**POWER SYSTEM**)

By

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REGISTRATION No. 2K16-PFE-011

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Year 2016

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DECLARATION BY THE SCHOLAR

I declare that the Synopsis entitled **"Intelligent Models and Algorithm for Deregulated Electricity Markets"** is prepared under the supervision of Dr. Y K Awasthi and Dr. Anwar S Siddiqui and submitted for the approval of Departmental Research Committee (DRC).

Signature of Supervisor *Signature of Co-Supervisor* *Signature of Scholar*

Intelligent Models and Algorithms for Deregulated Electricity Market

1. INTRODUCTION

In recent years the power sector is one of the demanding sources for electricity department and it is restructured with the improvement of system efficiency and economic solutions. The restructured power sector is known as the deregulated electricity market. The emerging technology of deregulated electricity market diminishes the monopoly behavior in trading and generation sectors. Hence the competition among various trading sectors is introduced all over the world. Besides that, the number of issues such as strategic bidding of supplier's, oligopolistic nature of trading sectors, misusing of market power, an adjustment in price demands and so on arises with regards to the sudden development of restructured power industry. Moreover, for a few decades, the government introduced the norms to increase the green energy over electricity markets by offering various support strategy and subsidies [1]. The deregulated electricity market [2]-[5] is primarily designed for a conventional fossil-fuel generation. In the deregulated market, all the participants are committed to delivering their power in several hours based on the day-ahead timeline. The initial commitment of power delivery in wind power generator differs due to the intermittent behavior of wind energy. Simultaneously, the market prices and environmental concerns of wind energy produce uncertainty behavior for wind power generators. Due to these impacts, participants are facing penalty criterion and act as strategic players in response to the deviation of the initial power commitment schedule. Random generation of power restricts the Wind Power Producer's (WPPs) to be included in the deregulated market of electricity linearly. Hence forceful intention is made by them to market their electric supply through several contracts.

In a perfect competitive deregulated market, power producers should bid their power with the marginal production cost. However, the real electricity that is deregulated in markets where two or more firms are participating in nature, where the demanders try to improve their gain by allotting their market rate larger than the original cost of production [2] [6] [7]. Further, the power producers face problems to optimize the bidding cost by knowing the construction cost, the expectation of rival behavior and technical limitations. This process is termed as strategic bidding problem [8] [9]-[11]. In order to model the strategic bidding problem, three basic approaches are used (i) the market gladding cost estimation is the cost per MWh

assigned by the largest price producer that is necessary to face the requirements, (ii) game theory and (iii) rival's bidding behavior estimation [12]. However, the forecasted energy price may vary from the real energy price since we considered several uncertainty factors such as transmission congestion, demand forecast error, rivals' bidding behavior and so on [13] [14]. Such a varying nature of market price may seek the trading risk of power suppliers [15]-[18]. Hence, the bidding strategy should be optimized with the bi-objective function of increasing their profit and minimizing their trade risk.

For increasing their profit (PF), generation companies (GENCOs) have introduced Unit Commitment (UC) program depending on the signal of cost (forecasted price) in the deregulated electricity market and hence called as the PF-based UC (PBUC) problem of the GENCOs [19]-[24]. For finding the GENCOs revenue, the PBUC problem has to be used by providing reserve prices and forecasted energy as input [25]. If the PBUC problem considers thermal ramp rate units, Dynamic economic dispatch (DED) deviates from uncomplicated economic dispatch (ED) [26]. Accordingly, several mathematical designs and respective methods for a solution have been introduced, yet they don't involve entire problems associated with decisions of long-term.

Essential characteristics of today's electrical grids are the reliable and unconfined power supply to modern society. However, many renewable energy sources of the wave, wind, solar and tidal for the production of electricity have an intermittent attribute by nature, and hence we cannot achieve the same state of energy supply using the conventional fossil fuel generation[12] [27] [28]. The loss of flexibility undertakes in the demanding loop. With the aid of pumped hydro energy storage (PHES) and neighboring electricity markets, trading efficiency can be achieved [1]. Beyond that flexibility is achieved from the requirements of the consumer over system necessities by deploying demand-side management (DSM) [29]-[33]. The primary goal of DSM is to vary the quantity or duration of the requirements of consumer's electricity using dynamic load shifting [34] [35].

2. RELATED WORKS

2.1Strategic Bidding Models

Biplab Bhattacharyya et al. [8] have presented the use of Genetic Algorithm (GA) and Differential Evolution (DE) techniques by minimizing the transmission loss as well as the

reduction in the operating cost of the system by exploiting Thyristor Controlled Series Compensator (TCSC), Unified Power Flow Controller (UPFC), Flexible AC Transmission System (FACTS) devices and Static VAR Compensator (SVC).

MuratFahrioglu [1] has investigated the extended mechanism design theory to implement efficient demand management contracts for power system industry. This contract has improved system security and the benefit of total utility by optimizing the right locations. Hence if the locational value has high electrical utility, it should offer more monetary incentives to attract more customers.

For minimizing the imbalance among the wind power producers and last power generation, Victoria Guerrero-Mestre et al. [19] have developed various strategies, and risk assessment wind farm sets to the current market that has been modeled using Conditional Value at Risk (CVaR) and mixed integer programming that is stochastic in nature. The developed analysis has shown that the WPP's obtained high profit when assuring a larger CVaR.

Duong Tung Nguyen and Long Bao Le [25] have suggested a desired power scheduling architecture with renewable energy for a MicroGrid (MG) by focusing on customer's heat comfort necessities as well as various system constraints. They have integrated the flexible, intelligent DSM of ventilation, air-conditioning (HVAC), and heating the load schedule by managing the energy issues of Micro Grid (MG) aggregator. It has increased its gain and reduced the quantity of renewable energy limitation.

A. E. Clements and A. S. Hurn, Z. Li [26] have studied the regional market of Queensland, in Australia. It was noted that bidding characteristics by generators prevail that is closely associated with the appearance of peak price event types that are subjected to several markets with deregulated electricity. Simultaneously, rebidding property by base-load producers soon after peak price events is addressed to have the worst impacts on the market processes. They have finalized that endorsement of electricity competition in markets includes worst factors unless the regulatory scheme is modeled to contradict strategic property by market contestants.

Sayyad Nojavan et al. [27] have presented a dual approach depending on Modified Particle Swarm Optimization (MPSO) and Information Gap Decision Theory (IGDT) to improve the

desired bidding scheme of the price-taker participant. This developed strategy has improved their own profits in the present electricity market.

J. Vijaya Kumar et al. [12] have presented a novel stochastic optimization approach said to be Fuzzy Adaptive Gravitational Search Algorithm (FAGSA) to find a solution for desired bidding scheme issue in a group dependent electricity market. This method has successfully examined on IEEE 75-bus system as well as a 30-bus system and hence improved the total profit of the participants.

In 2016, Subhojit Dawn and Prashant Kumar Tiwari [28] have worked on simple and reliable optimization method to assign the UPFC and TCSC with the help of wind generator in the deregulated power system. Moreover, this proposed method is done on the basis of changes in variables for controlling UPFC and TCSC plans. Meanwhile, this method is done on the enhanced IEEE 14 bus as well as IEEE 118 bus benchmark system.

Kailash Chand Sharma et al. [9] have developed the strategic performance of WPPs are designed by a Stochastic Cour-not model in a group that is dependent on the current electricity market. Uncertainty in the wind and sufficient prices are taken into account for measuring the required gain. The computational burden of wind vagueness has addressed by Auto-Regressive Moving Average (ARMA) design, which is then reduced using Simultaneous Backward Reduction method. When focusing imbalance charges and vagueness in wind power, strategic WPPs have developed their desired payoff or gain via the bidding strategy of implemented Nash equilibrium [NE]. NE has been achieved by a move towards a payoff matrix. The bidding strategy technique has experimentally proved on 3 and24-bus system with three WPPs and thereby increased the WPPs profit.

S. Chellam and S. Kalyani [10] have proposed a new strategy for evaluating the transmission overcrowding price by deploying tracing policy under markets with deregulated electricity. An optimization framework has been solved by adopting the PSO algorithm in which the results were analyzed on enhanced IEEE 30 and 69 Indian practical bus systems. From the price owing to lose and fixed construction price, the transmission overcrowding cost is calculated.

A. K. JAIN et al. [16] have formulated the Bi-Level Multi-Objective Optimization Problem (BLMOOP) for optimal bidding strategy, where the small problem solves the gladding process in markets for reducing the customers' payments performed by the system operator (SO) and the high-level issues increases the individual generators' gain and minimizes their risk. The Pareto-optimal solution to this issue has been achieved by deploying the constraint technique. In order to derive an efficient solution, a fuzzy decision maker has been used among the Pareto-optimal solutions of the BLMOOP. The ABC algorithm of comparatively novel population method has been adopted to attain the best resolution of the upper-level problem.

2.2Unit Commitment Problem in Deregulated Environment

In order to deal with the difficulties and insufficiencies of the incorporated solution of long-standing electric power scheduling of GENCos and scheduling participating in a deregulated market M.M. Lotfi and S.F. Ghaderi [11] have proposed a hierarchical multi-level technique based on fuzzy. This method targets to introduce a connection between the day-ahead market scheduling and the long-standing decision execution. Under the guidance of desired membership programs for fuzzy methods and certain critical data, the internal and external dynamisms are effectively captured and thus improved the flexibility and consistency of decisions. The process of planning the scheduling issues and electric power, clear constraints were presented to design complex problems. A technique called interactive solution with coordination, feedback techniques, and imposition, using undulating horizon scheme is offered. The outcomes of profits from GenCo have applied to offer practicable and appropriate plans for the current unit issues an obligation.

In 2015, Prateek Kumar Singhal [15] had successfully implemented a new Binary fish swarm algorithm (BFSA) to explain the PBUC issue for 100 as well as 10 thermal units in a present economical market of electricity by taking into consideration of the reserve generations and power concurrently. The enclosure of rising in constraints of the thermal unit in solving of PBUC issue has minimized the entire gain of GENCOs; however, it shapes the issue more practical. Besides, the similar issue in PBUC was brought to a solution by employing priority list (PL), dynamic programming (DP), Lagrange relaxation (LR), genetic algorithm (GA) and binary artificial bee colony algorithm (BABC) methods.

2.3 Management of Demand Side in Electricity Market

Paddy Finn and Colin Fitzpatrick [34] have analyzed the probabilities for the functioning of cost dependent requirement responsibility by a user from industry to improve their consumption of electricity created by the wind from changing their command over a period of least costs. Achievements have shown that when processing extreme cost duration with less or no gain with respective to the utilization of wind energy; requirements were moved towards least cost duration thus improving the user's conservation of wind production by about 5.8% for all 10% saved on the user's standard unit charge of electricity.

Javier Campillo [35] have discussed the economic impacts on the customer from adopting a Real-time price (RTP) electricity agreement against the usual one-year preset cost with invariable electricity consumption profiles. To achieve this, seven years of periodic historical electricity utility for four hundred costumers in central Sweden were adopted to evaluate their periodical pay-slips by using those two kinds of price agreements. Results suggested that user's living in Sweden might be shifted to agreements of RTP and obtained financial profits, though there is no change in their electricity usage patterns.

3. PROBLEM DEFINITION

Author [citation]	Adopted methodology	Features	Challenges
Murat Fahrioglu [1]	Statistical analysis	• Analysed quickly • Useful for benchmarking purposes.	• Not suitable to evaluate user opinions • Requires technical expertise
Biplab Bhattacharyya et al. [8]	Genetic algorithm	• Solves the solution structure and solution parameter problems	• It cannot assure constant optimization
Kailash Chand Sharma et al. [9]	Auto-Regressive Moving Average (ARMA) model	• simpler structure	• Process behavior is not considered
S. Chellam and S. Kalyani [10]	PSO	• fast convergence • easy to implement	• trapped in the local area
M.M. Lotfi and S.F. Ghaderi [11]	fuzzy hierarchical bi-level approach	• Simple and very flexible model	• only triangular fuzzy numbers to be used • the computational requirement is tremendous even for a small problem

J. Vijaya Kumar et al. [12]	fuzzy adaptive gravitational search algorithm (FAGSA)	• High accuracy	• Complexity is more
Prateek Kumar Singhal [15]	Binary fish swarm algorithm (BFSA)	• High accuracy • Avoid convergence to a non-optimal solution	• Computation time increases
A. K. JAIN et al. [16]	ABC algorithm	• Ability to explore local solutions • Easy to implement	• Slow to obtain an accurate solution
Victoria Guerrero-Mestre et al. [19]	Stochastic mixed integer linear programming	• suitable for ciphers	• no optimality conditions
Duong Tung Nguyen and Long Bao Le [25]	Monte carlo	• capability to feature in a series of values for several inputs	• underestimate the probability of extreme bear events
A. E. Clements and A. S. Hurn, Z. Li [26]	Probabilistic models	• Based on a firm theoretical foundation • the optimal ranking scheme is justified theoretically	• Poor computation in practice
Sayyad Nojavan et al. [27]	modified particle swarm optimization (MPSO)	• Simple and efficient computations	• Difficult to select inertia weight values. • Only small benchmark functions to be used to test.
Subhojit Dawn and Prashant Kumar Tiwari [28]	Personalized optimization	• Simple and sophisticated	• Basic greedy search is used
Paddy Finn and Colin Fitzpatrick [34]	Statistical analysis	• Analysed quickly • Useful for benchmarking purposes.	• Not suitable to evaluate user opinions • Requires technical expertise
Javier Campillo [35]	Regression analysis	• Accurate • Easy to implement	• Difficult to understand the computation

4. PROBLEM FORMULATION

The unstable and alternating feature of renewable energy production includes a major confront to amalgamate these possessions into power systems. In a current energy mart, the production stations surrender supply bids and the energy provision industries allow power

requirements instantly for the successive day to the operator of the market. The submission of requirements and supply bids lies in the variety of cost-quantity pairs. The operators in the market process the demand offers and supply bids after estimating the cost that verifies the degree of trade and the marginal cost of the market. The complication of the trouble involves obtaining a decision dependent on defective details of cost in the market, producer face difficulties in introducing its required bidding scheme. In a defective electricity market, a manufacturer might build up a bidding scheme to develop its individual PF. A manufacturer should formulate resolutions depending on adequate information. A manufacturer may not have knowledge about the real system MCP earlier, as the MCP is based on the bidding scheme of various contestants in the market that is deregulated, a producer may not know the MCP in advance. Hence, the desired bidding policy is a demanding assignment for manufacturers. In a strategic bidding problem, risk due to price volatility is a serious concern, and it creates the need to perform the risk assessment. In the economical deregulated markets, suspicions are found and are not trivial. Furthermore, from the market variations, new uncertainties are formed which will also complicate the problem. The accuracy of cost prediction on the gain dependent designs are analyzed and they are developed in an uncertain environment [11]. Many renewable energy sources like a wave, wind, tidal, and solar for electricity generation are intermittent by nature, and therefore, it is difficult to manage in the same level of service by compensating with the conventional fully dispatchable fossil fuel generation. Due to the insufficiency in dispatch-ability of energy resources, the flexibility of the demanding loop gets lost. With the aid of pumped hydro energy storage (PHES) and neighboring electricity markets, trading efficiency can be achieved [1]. Besides that, it is possible to achieve flexibility from the requirements of the user's over necessities of the system by exploiting DSM.

5. RESEARCH OBJECTIVES

The primary objectives of the research are as follows.

- To critically review the literature relevant to the deregulated market and the economic efforts to handle the environment
- To investigate the state-of-the-art demand side management on the current supply-demand scenario
- To analyze the unit commitment problem and the algorithms reported in the literature to handle it

- To demonstrate the features and challenges reside on bi-level strategic bidding, bidding problem models with constraints and multiple objectives
- To understand and characterize various meta-heuristic and intelligent algorithms that handle the challenges in the deregulated electricity market
- To propose hybrid intelligent algorithms to solve the primary challenges of deregulated electricity market such as demand side management problem, unit commitment problem and strategic bidding problem.

6. ADOPTED METHODOLOGY

Based on the objectives of the research, the methodology is segregated into three phases. In the first phase, intelligent modeling techniques will be derived for forecasting and further to derive the mathematical model for supply-demand scenarios in the deregulated electricity market. Since artificial intelligence has found success in many applications, this proposal intends to deploy feed forward neural network with meta-heuristic training to model the demand side management principles. In the second phase of the research, precise models and algorithms will be developed to solve the unit commitment problem.

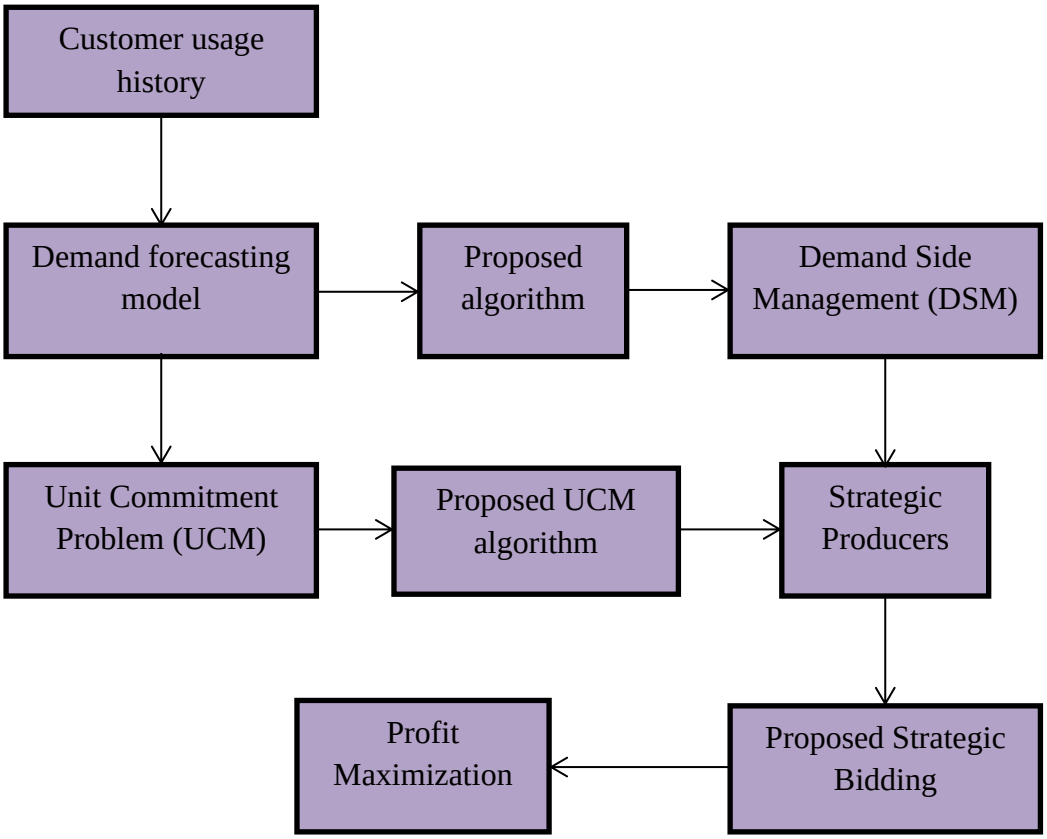

Figure 1: A proposed methodology for economic operation of the deregulated electricity market.

By considering the parameters under a deregulated environment, the more precise objective model will be derived for the unit commitment problem. Subsequently, adaptive swarm intelligence will be introduced to solve the problem model. The third phase of the research deals with the strategic bidding persists among the market participants. Being inspired by the constraint-less objective models, a sophisticated bidding model will be exemplified and derived. The adaptive swarm intelligence will be exploited further to find a solution for the implemented bidding design.

7. EXPECTED OUTCOME

The implemented models, as well as the algorithms, will be simulated in the working platform of MATLAB. IEEE benchmark test bus systems will be used to perform an experimental investigation. The state-of-the-art models will be developed, and the comparative investigation will be carried out. Since intelligent models and swarm intelligence play key role in our research, the traditional algorithms will be developed, and the performance of the proposed algorithms will be demonstrated through convergence test, statistical test, and computational complexity. Moreover, the conceptual metrics such as unit commitment cost, and bidding profit will also be exploited to demonstrate the achievement of research objectives.

The intelligent models will be investigated for its feasibility with Indian markets using Indian utility systems such as 75-bus Indian utility system.

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SHORT SYNOPSIS

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